Worldwide Assessment of Stern Launch Capability

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Small boats are essential to the successful execution of many to the Coast Guard's missions. The ability to launch and recover boats in a broad range of environmental conditions is essential to complete these missions. The U.S. Coast Guard's Engineering Logistics Center was requested to develop a design and assessment tool to assess the design, feasibility, benefits, and risks associated with stern launching and recovery of boats. A systematic approach was taken to develop a of set of boat launching criteria, define an analysis method, perform seakeeping tests, perform a percent time operability (PTO) analysis, perform a preliminary risk analysis, and perform a worldwide assessment of stern launch capability. This paper is limited to the worldwide assessment of stern launch capability.

The purpose of the worldwide search of candidate vessels operating with stern deployment systems was to determine their design criteria and to determine their operating characteristics. The ships identified ranged in length from the U.S. Coast Guard's own 87-ft WPB (Marine Species Class) to the 300-ft Japanese Coast Guard Cutter Erimo (ex Ojika). The investigation involved meeting with owners, operators, and designers to determine the different characteristics of their stern deployment systems. Standard sets of questions were developed for the owners and operators in order to have comparative answers. These questions were directed toward the design and operation of the deployment systems as well as any enhancements that would be desirable as a result of lessons learned.

The investigation concluded that stern launching systems could be divided into two distinct types: the docking well and the ramp. Support for the small boat can be provided three ways: shape the ramp to suit the boat's hull, provide fixed longitudinal supports for the hull, or provide a moveable cradle. The boats used in all situations were known as fast response craft (FRC). They were represented by rigid hull inflatable boats (RHIB) and other small fast boats. This paper will discuss the findings of the research.

INTRODUCTION

The Naval Architecture Branch of the U.S. Coast Guard Engineering Logistics Center was tasked to develop criteria for design and evaluation of stern launch and recovery systems for small boats from ships ranging in length to 400 feet long. The process of developing the criteria involved a worldwide search to identify candidate vessels that presently operate stern deployment systems. Stern deployment systems were identified in many countries on many vessels. Seven vessels of various sizes were identified for investigation to determine the effectiveness of their deployment systems. In addition, the vessel's designers were contacted in an effort to determine the design criteria they had employed during the design. The ships ranged in length from the U.S. Coast Guards own 87' WPB to the 300' Japanese Coast Guard Cutter *Erimo (ex Ojika)*.

In preparation for the shipchecks, a standard list of questions was developed that would provide answers that could be compared across all the vessels. The questions focused on the operation of the deployment systems as well as any changes that would be desirable. A similar set of questions was developed for the system designers to assess the design criteria used and to determine what, if any, changes would be made for the next generation of stern deployment systems.

The following ships were visited during the course of our research:

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a. Japanese Coast Guard Cutter, *Erimo* in Tokyo, Japan
b. Mexican Navy ship, *Justo Sierra* in Acapulco, Mexico
c. U.S. Navy Patrol Craft, *Tornado* in Little Creek, Virginia
d. Canadian Coast Guard ship, *Gordon Reid* in Victoria, British Columbia, Canada
e. Netherlands Antilles and Aruba Coast Guard Cutter, *Jaguar* in Curaçao, Netherlands Antilles
f. Finnish Frontier Guard ship, *Telkkä* in Turku, Finland
g. USCG Coastal Patrol Boat, *Hammerhead* in Baltimore, Maryland

Visits to ships, ship owners, and designers were performed to establish the operating characteristics of the stern launching/recovery systems. The main areas of their design and operation that were investigated are as follows:

a. Size of ship
b. Type and size of small boat
c. Types of systems
d. Ramp design considerations
e. Equipment
f. Launch and recovery operations
g. Time intervals for launch and recovery
h. Design and operational Sea States
i. Manning requirements
j. Training

Size of Ship

A table 1 summarizes the mother ship characteristics and the type of deployment system used. The vessels ranged in size from 87 feet for the U.S. Coast Guard's Coastal Patrol Boat *Hammerhead* to 300 feet for the Japanese Coast Guard's ship *Erimo*. The length of the ship affects the motions and accelerations at the stern. The longer the ship the higher the accelerations and the greater the motions, limiting use in higher sea states.

Table 1 – Ship and Ramp Characteristics

Ship	Length of Ship	Type of Stern Ramp
Erimo	300'-0"	Well Dock
Justo Sierra	244'-0"	Fixed Ramp
Tornado	179'-0"	Fixed Ramp
Gordon Reid	163'-10"	Hinged Ramp
Jaguar	140'-5"	Fixed Ramp
Telkkä	161'-5"	Fixed Ramp w/Cradle
Hammerhead	87'-0"	Fixed Ramp

Type and Size of Small Boat

All vessels visited used Fast Response Craft (FRC) for deployment from the stern. The majority of the FRCs were of the Rigid Hull Inflatable Boat (RHIB) type. Two ships used small boats other than RHIBs. One of the FRCs was made of fiberglass with an operator's cockpit located amidships. The other FRC was an aluminum hulled Interceptor with an operator's cabin and seats for a boarding party of four. The majority of the small boats carried were between 7 and 7½ meters (23 to 24 feet) long. The largest boats carried were 11 meters (36 feet) long and the smallest was 5.5 meters (18 feet) long.

In addition to the stern launched small boats, four of the largest vessels, *Erimo*, *Justo Sierra*, *Gordon Reid*, and *Jaguar*, also maintained the capability of launching small boats over the side. The small boats for over the side launching on the "*Gordon Reid*" and "*Jaguar*" were for emergency use only. On the *Erimo* and *Justo Sierra*, the side launched boats were in addition to their stern launched boats. While the Japanese preferred to use their side launched boat for normal boat operations, the Mexicans preferred to use their stern launched boat.

Types of Systems

The stern deployment systems can be separated into two types as summarized in Table 1. The first type is a well dock as exhibited on the Japanese Coast Guard ship, *Erimo*. In this type of deployment, a stern well is flooded and the small boat powers its way out of the ship. The second type is a ramp, either fixed or hinged. The second type is more widely used. The ramps can be either shaped to fit the hull of the FRC or flat with longitudinal runners that support the FRC's hull. Both types of ramps use a friction reducing material, such as Ultra-Poly or Teflon. This provides a low friction surface that permits the FRC to slide down the ramp easily. One of the ships, *Gordon Reid*, has a ramp that is hinged and can quickly raise the FRC to deck level, removing the boat completely from the water.

Ramp Design Considerations

The ramps can be categorized as two different types. The first type is a flat ramp that uses tubular bunks to support the RHIB. The second type of ramp is a shaped ramp where the ramp surface is built to suit the shape of the FRC and lined with friction reducing material. The slope of the ramps varied between 7° and 18°.

The Finnish Frontier Guard ship, *Telkkä*, used a cradle on rollers to deploy and recover the FRC. The wheeled cradle of the *Telkkä* permitted launching the FRC with a low ramp angle. The cradle, in the deployed position, became a ramp extension permitting the launch and recovery of the RHIB over a sill that is above the waterline.

Physical constraints within the ship can dictate the use of low ramp angles. With low ramp slopes, the deployment system design must account for overcoming the static friction in order to self-launch.

In general, vessels with a ramp slope of 12° and higher were capable of launching the FRC without assistance. The use of friction reducing materials, such as Ultra-Poly and Teflon, was common on the sliding surface of most of the ramps.

The stern ramp on the *Gordon Reid is* hinged. During launch and recovery operations, the ramp is hinged down 15°. When not performing launching or recovering operations, the ramp is brought up to the deck level providing easier access to the FRC and removing it from the water for storage and/or maintenance. The ramp surface is constructed of grating. The surface of the grating acts to dampen the wave motions in the ramp making launch and retrieval easier. At the bottom end of the ramp there is a pad of friction reducing material to keep the bow of the FRC from coming in contact with the grating during launch and recovery.

Ramp width is determined by adding a suitable clearance between the FRC and the side bulkheads of the ramp. The clearance must be sufficient to give the coxswain confidence when entering the ramp, but not so much that the FRC will come to rest out of position. The clearances observed on the ships visited varied widely from as small as four inches to as much as 18 inches. The entrance to the ramp should be rounded and smooth to permit the coxswain to fend off them as the FRC is powered into the ramp well. The use of square or sharp corners will cause damage to the collar of RHIBs.

The ramp openings are closed either by doors that hinge outward or by gates that hinge up. With outward hinging doors, they can be used to form a "funnel" to help the coxswain guide the FRC into the ramp. The gates, that hinge upward, must be designed so that there is sufficient clearance for the worst sea conditions the stern ramp is expected to encounter. The coxswains of FRCs that enter ramps with gates noted that they feel they could hit the open gate if the pitch gets too great.

The sill depth was the biggest factor governing available recovery time. The vessels investigated had sill depths that varied from one foot above to 34 inches below the design waterline. The *Telkkä* is an ice strengthened ship and was designed with the ramp sill that is above the waterline to prevent ice from entering the ramp area during backing operations. The *Gordon Reid* has a sill depth of 34" and is the only vessel that can routinely perform stern ramp deployment operations in sea states of five and greater. All other ships were designed to operate in sea states of four and lower. The greater sill depths generally translate into the ability to operate in higher sea states.

Equipment

The FRCs or small boats observed on the vessels investigated fell into two categories, RHIBs and others. Table 2 summarizes the characteristics of the boats used. The majority of the small boats were RHIBs between 7 meters and 7½ meters long. Only two ships used non-RHIBs, the *Justo Sierra* that used an 11-meter, aluminum hulled, Interceptor and the *Erimo* that used a fiberglass fast response craft. Power was provided by diesel engines in all but one vessel, the *Gordon Reid* that use gasoline powered outboards. The outboard powered RHIB is very responsive to throttle and very maneuverable. All the diesel powered small boats used water jet propulsion with the exception of the Navy's 7-meter RHIB that used an I/O drive. The larger 11-meter boats used twin water jets for propulsion. The advantage of the water jets is there is no appendage that hangs below the hull to interfere with launch and recovery operations. However, the directional stability of waterjets in the stern wake is limited and all but the most experienced coxswains experienced great difficulty transiting the wake. With I/O drives and outboards there is better directional stability in the ship's wake but the lower units can interfere with the ramp. On the *Tornado* the lower unit is raised before the RHIB is winched completely up the ramp. On the *Gordon Reid* the hinged portion of the ramp ends before the lower units of the outboards preventing any interference.

Table 2 – Ship and Boat Characteristics

Ship	Boat Type	Propulsion
Erimo	Fiberglass FRC	Waterjet
Justo Sierra	Aluminum FRC	Waterjet
Tornado	RHIB	I/O & Waterjet
Gordon Reid	RHIB	Outboard
Jaguar	RHIB	Waterjet
Telkkä	RHIB	Waterjet
Hammerhead	RHIB	Waterjet

One nice feature of the RHIBs used on the some of the vessels was an inflatable collar that wrapped completely around the stern. The additional collar around the stern provided flotation for the RHIB's stern preventing submerging the stern during launch and recovery. On RHIBs equipped with outboards, they also prevent submerging the engines and ingesting water into the carburetors during launch and recovery operations.

The mechanical equipment used on the ships for the operation of the stern doors, winch, and hinged ramp were powered by hydraulics. In a few cases the retrieval winch was electric. Hydraulic cylinders powered all of the stern doors and gates. Where the stern doors and gates closed to form a watertight seal, smaller hydraulic cylinders were used to hold the doors closed. Power for the hydraulics was supplied either by a dedicated hydraulic power unit or as part of the ship's hydraulic system.

Launch and Recovery Operations

All the ships responded that they could launch the small boat in any sea condition that the small boat could safely handle, but that recovery was considerably more difficult. The majority of the ships preferred launching with the ship's course set directly into the waves (0°). As an alternative, they would fall off the wave by up to 30° to reduce the pitching motions. Some of the vessels preferred to run with the waves, at the same speed as the waves. This gave them the optimum condition for deploying their RHIB. The Canadian Coast Guard ship *Gordon Reid* preferred to run in the trough of the waves (heading of 90° relative to the waves) when performing boat operations in high sea states. The *Gordon Reid* found it easier to launch and retrieve the RHIB with in the rolling seas. Model tests performed for the ship, before construction, determined that boat operations could be performed in higher sea states when operating in beam seas.

During recovery, most of the ships preferred same course they used for launch, head seas to 30° off the waves. The reasons they prefer their recovery directions are the same as for launch. The mother ship speed for recovery is nearly the same for recovery as launch. However, one vessel's recovery speed was doubled to nearly 10 knots or twice that of other ships. At the higher recovery speed, the water jet driven RHIB must travel at a higher speed where it has better directional stability.

Launching and recovery procedures for all the FRCs are very similar. To launch:

1. The captain sets the course and speed of the mother ship.
2. The FRC is readied for launch including a check of all equipment.
3. Command of the launch operation is passed to the coxswain
4. Stern doors are opened
5. When the coxswain is ready, the FRC is lowered down the ramp, with the winch, to submerge the engine water intakes and the engines are started
6. When the coxswain determines that all conditions are go he gives the command to release the winch line
7. The bowman trips the quick release hook and the FRC slides down the ramp and out the transom.
8. The coxswain backs the FRC away from the ship
9. The winch line is retrieved and the transom doors are closed.
10. Command of ship operations returns to the captain.

There are a few exceptions to this procedure. One of the most notable is in step 5. Some FRCs are designed to run the engines dry for a short period of time and do not need to be lowered into the water before starting. For those, the engines are started, the quick release is pulled, and the boat slides down the ramp and out the transom. Another exception is in the control of the launch. On some ships, a deck hand is designated as the launch control officer, not the coxswain. He is responsible for determining when to launch the small boat.

As in the launch sequence, nearly all recovery operations are performed in the same manner. The steps followed are:

1. The boat coxswain requests permission to board.
2. The captain sets the course and speed of the mother ship for recovery
3. When course and speed are constant, command of the recovery operation is passed to the coxswain
4. The stern doors are opened
5. The winch line is paid out and held along side the ramp.
6. The coxswain brings the FRC to a position in the center of the ship's wake at about two boat lengths behind the ship.
7. The coxswain must time his entrance into the ramp to coincide with the sill's greatest submergence. When the coxswain sees his opportunity, he accelerates the FRC into the transom opening and up the ramp.
8. The winch line is passed to the bowman who attaches it to the FRC.
9. The FRC is then winched up the ramp to the stowed position.
10. The stern doors are closed.
11. Command of ship operations returns to the captain.

There are a few differences between the various ship's recovery procedures, most notable would be the method for capturing the RHIB during recovery. On the *Telkkä*, a mechanical arm captures and holds the RHIB in the cradle and then the cradle is winched into the ship. On the *Hammerhead*, the RHIB is driven all the way up the ramp, captured by a lasso, and held in place until the winch line is connected and the boat pulled to the stowed position.

Time Intervals for Launch and Recovery

The ship speed for most launchings was between 3 and 6 knots. This gives the mother ship enough forward motion to maintain her course but still slow enough for the RHIB to escape the stern wake after launch.

Launching times varied directly with the launching procedure. The launching time is defined as the time from when the command to launch is given until the boat is clear of the transom. The quickest launches were experienced on those ships where the diesel engines were started dry. On these vessels, after the stern gate was opened all that was involved in the launch was to pull the quick release mechanism. Adding a winch to lower the boat into the water before starting the engines increased the launch time to about 10 – 15 seconds. When the cradle or mechanical assistance was needed to launch the boat, the time increased and approached a maximum of 35 seconds.

The recovery times are typically quicker than launch times. The recovery time is defined as the time it takes from when the coxswain decides to enter the ramp until the RHIB grounds on the ramp. At that point, the RHIB is attached to the winch and hauled up to the storage position. The recovery times were found to be nearly constant at 10 to 12 seconds for all vessels.

Design and Operational Sea States

It was interesting to note that for several deployment systems the maximum operating sea state is less than the design sea state.

The sea state limit on operating is dependent on the ramp design and the coxswain's ability.

The design of the *Gordon Reid* employs three factors that permit operation in the higher sea states. The first is a deep sill submergence (34" at the design waterline). With this depth, the sill is submerged during all operations. The second design feature is the hinged ramp. This allows the crew to enter and exit the boat from the deck, on the level. It also removes the RHIB from the water quickly. Without it, the seas in the ramp would pound the stern of the RHIB until the stern doors closed. The third design factor is the clearance between the RHIB and the side bulkheads of the ramp. On the *Gordon Reid,* there is a clearance of 13 inches on each side of the RHIB. This gives the Coxswain a target with some forgiveness for an off center recovery. The intersection of the stern and the ramp bulkhead is generously radiused, providing a smooth entry to the ramp well. This prevents damage to the RHIB collar during recovery operations.

Stern Wake Influence on Recovery

The wake of the mother ship is a hydrodynamic problem that has not been numerically analyzed due to the complexity of its nature. The factors that influence the wake are the ship's hull form and the propeller wash. They combine to form turbulent eddies that make slow speed transit of the wake difficult. The effects of the wake are presently best understood through empirical observations. Nearly all the ships had two propellers. During launch and recovery operations, it was observed that the wake would form a depression between the two propeller washes. This trough would aid in centering the RHIB during recovery operations.

All the small boats exhibited difficulty navigating the wake and keeping the boat on a straight in approach. The stern wake made it difficult to maintain directional control of the small boat. As the sea states increased, the wake effects worsened. The natural tendency of the coxswains was to over steer when making the approach to the ramp. In all sea states, except flat water, a last minute correction was observed as the RHIB traversed the stern wake and entered the ramp.

The slow speed directional control of the RHIB, when equipped with water jets, is minimal making transit of the wake difficult. The approach speed of the RHIB is approximately twice the speed of the mother ship. On one ships surveyed, to maintain better directional control of the RHIB, the recovery speed is increased to between 6 and 10 knots. This permits RHIB recovery speeds of between 12 and 20 knots, providing better directional control of the RHIB during recovery.

RHIBs equipped with outboard propulsion and outdrives exhibited better directional control at the recovery speeds than did the waterjet-propelled boats.

All stern deployment systems observed are located on the ship's centerline. The recovery course of the RHIB is centered between the more turbulent parts of the wake produced by the propellers. Better maneuverability and directional control of the RHIB can be maintained, increasing the likelihood of a successful recovery.